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EVALUATION OF ENVIRONMENTAL AND ECONOMIC BENEFITS THROUGH USE OF SYNTHETIC MOTOR OILS

FINAL REPORT
AFLRL NO. 91

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by

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Prepared by

U. S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas

under contract to

U. S. Army Mobility Equipment Research and Development Command
Energy and Water Resources Laboratory
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Cost and environmental benefits of extended-drain engine lubrication were evaluated by means of a two-year field program at Letterkenny Army Depot, Pennsylvania. Four MIL-L-46152 crankcase lubricants (two mineral and two synthetic-base) were utilized in routine post operation. Each lubricant was assigned to one of four 25-vehicle fleets, and each fleet then operated

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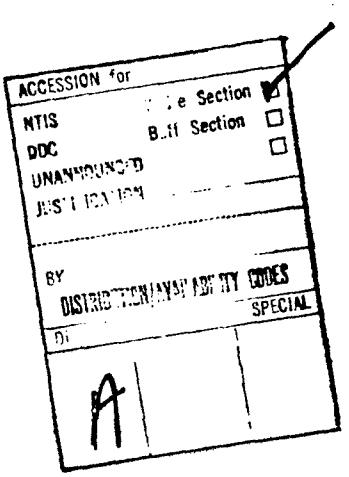
20. ABSTRACT (continued)

exclusively on that lubricant. During this time there were no engine failures that could be attributed to the extended-drain program. Therefore, it is concluded that (a) extended-drain engine operation has potential for both economic and ecological benefits to Army field operations, and (b) the synthetic lubricants employed showed no particular performance advantages over the mineral oils. Consequently, the higher cost of synthetic lubricants would make them less attractive for widespread Army utilization.

FOREWORD

The work reported herein was conducted at Letterkenny Army Depot, Chambersburg, Pennsylvania, by the U.S. Army Fuels and Lubricants Research Laboratory (AFLRL) located at Southwest Research Institute in San Antonio, Texas, under Contract No. DAAG53-75-C-0232. The Contracting Officers' Representative for the program was Mr. Forrest W. Schaekel, USAMERADCOM, DRDME-GL, Energy and Water Resources Laboratory, Fort Belvoir, Virginia.



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INTRODUCTION

A 1974 Development and Readiness Command (DARCOM) survey revealed that approximately one million gallons of crankcase drain oil requires disposal each year within the DARCOM complex alone. Prior to recent dramatic reversals in ecological and energy policies, this oil had been used on road surfaces for dust control or burned in open pits. Therefore, since a need existed to reduce the quantity of used oil generated, this program was begun to evaluate the environmental and economic impact through extended oil drain intervals. The program was conducted at Letterkenny Army Depot, PA by the U.S. Army Fuels and Lubricants Research Laboratory under contract to the U.S. Army Mobility Equipment Research and Development Command. The program ultimately resulted in:

- Use of four distinct military specification qualified lubricants (two mineral and two synthetic-base) in four separate fleets of 25 administrative vehicles each at Letterkenny Army Depot, Pennsylvania (LEAD).

- Program planning (including lubricant and vehicle selection) by MERADCOM Energy and Water Resources Laboratory, Fort Belvoir, Virginia.

- Liaison, coordination and drain-oil sample analysis by AFLRL staff to define benefits and/or disadvantages in such operations as compared to parallel operations with currently-used mineral oils on periodic drain schedules.

Other programs relative to the Army's use of synthetic lubricants and/or extended-drain oil intervals are shown in the selected bibliography section of this report.

DETAILS OF TEST

Test Plan

The test plan for this two-year evaluation at Letterkenny Army Depot, PA consisted of the following:

- Selection of 100 administrative-type vehicles, to be arranged in four (4) 25-vehicle fleets.
- Selection of two (2) mineral and two (2) synthetic-base lubricants.
- Identifying the four lubricants with a distinctive color code (Red, Blue, Green and Yellow) and assigning each to one of the 25-vehicle fleets.
- Providing maintenance personnel with vehicle preparation instructions, i.e.,:
  - Oil/filter change procedure.
  - Engine oil flush prior to receiving new change of oil.
  - Stenciling color code in conspicuous location under hood and placing appropriate colored tag on engine oil cap.
  - Procedures for collection of monthly 50-ml used oil sample.

Test Materials

It should be emphasized that all fuels and lubricants used in this program were military specification items.

a. Test Fuel

VV-G-001690A special grade unleaded gasoline was used throughout this program. This gasoline had been utilized in all vehicles at LEAD since 1972. Table 1 shows average properties of this gasoline. These data show the fuel to be well within specification limits, and typical of unleaded gasoline currently marketed throughout the United States.

TABLE 1. FUEL PROPERTY SUMMARY

Property	VV-G-001690A Specification	Average Analysis
Lead g/gal	0.05 (max)	0.013
RON	91	94.7
MON	83	83.8
(R+m)/2	87 (min)	89.3
FIA % Vol		
Aromatics	45.0 (max)	27
Olefins	Report	26
Oxidation Stability	240 (min)	610

b. Test Lubricants

Table 2 presents physical properties and chemical compositions of the four test lubricants, all qualified products under MIL-L-46152. The first two, AL-5009-L and AL-5680-L, are synthetic-base while the last two (AL-5889-L and AL-6095-L) are mineral-base oils. AL-5889-L being the lubricant currently in use at Letterkenny Army Depot, and AL-6095-L, a mineral-base lubricant which was expected to be of a higher quality level than the Army contract lubricant. Each test lubricant was procured from a single batch in sufficient quantity to last for the entire 24-month program. Drum-to-drum analyses for each lubricant showed no significant variation in composition or physical properties.

Test Fleet

Of the approximately 225 commercial vehicles at Letterkenny Army Depot, 100 were selected for this evaluation based on type of activity, age of vehicle, and mileage. Vehicle selection was confined to spark ignition powered vehicles which would have been expected to remain in service for at least two years in accordance with policy on turn-in due to age and/or mileage. The vehicles selected represented six (6) manufacturers (Ford, Chevrolet, Dodge, International Harvester Corporation, American Motors Corporation and Checker Motor Company) and ranged in year of manufacture from 1967 through 1974. Total vehicle

TABLE 2. PHYSICAL PROPERTIES AND COMPOSITION OF MIL-L-46152 TEST LUBRICANTS

Lubricant and Fleet Color Code Lubricant Code Type	Blue AL-5009-L Synthetic	Green AL-5680-L Synthetic	Red AL-5889-L Mineral	Yellow AL-6095-L Mineral
SAE Description:				
Performance Classification (J183a)	SE/CC	SE/CC	SE/CC	SE/CC
Viscosity Classification (J300c)	10W-30	10W-40	10W-30	10W-30
Properties				
Vis at 210°F, cSt	9.9	14.78	10.4	12.29
Vis at 100°F, cSt	56.9	89.7	68.5	77.2
Viscosity Index	178	183	150	167
TAN	3.1	2.6	1.9	2.4
TBN	6.9	8.6	9.9	10.1
Flash Point, °F	421	466	443	415
Pour Point, °F	−55	−40	−35	−40
API Gravity at 60°F	29.1	22.0	28.6	28.3
Composition, wt %				
Sulfur	0.30	0.28	0.52	0.57
Phosphorous	0.13	0.10	0.12	0.20
Barium	0.31	Nil	Nil	Nil
Calcium	0.03	0.28	0.20	0.37
Zinc	0.10	0.11	0.18	0.13
Sulfated Ash	1.13	1.10	1.12	1.34

starting mileage ranged from 8608 miles to 83,566 miles. The vehicles, once identified, were then divided into four groups of 25. Each group was identified by a color code (Red, Blue, Yellow and Green). Every attempt was made to equalize the fleets (as much as possible) by vehicle type, service, age and mileage.

Tables 3, 4, 5 and 6 provide information on vehicles assigned to the four fleets by color code.

After vehicle identification and preparation, but prior to program initiation, three vehicles were deleted from the program due to an Army Materiel Command (now DARCOM) reduction in the Government Transportation Authority (GTA) fleet at Letterkenny.

Because of the vehicle reduction at Letterkenny, these vehicles were not replaced with other like vehicles for the evaluation. Those vehicles deleted were:

Vehicle Type	Manufacture	Year	Bumper Number
Bus, 12 Pass.	Checker	1969	AO 893
Truck, S&P	Chev.	1967	AO 528
Bus, 25 Pass.	IHC	1972	Unknown

Vehicle Preparation

The following vehicle preparation instructions were utilized for all vehicles in each of the four fleets:

> Each engine was operated for adequate time to reach normal operating temperature, oil was drained from crankcase, the old filter removed, housing cleaned and new oil filter element installed. The engine was then flushed with the properly color-coded test lubricant and after flushing, the crankcase was charged with the corresponding color-coded test lubricant. Vehicle mileage was recorded and the following precautions taken to insure use of the proper test lubricant throughout the evaluation.

a. A tag was placed in the driver's compartment to alert the driver that the vehicle was a test vehicle.

b. A plastic-coated and color-coded tag was placed on the vehicles' oil dipstick to alert maintenance personnel of its test status and the lubricant to be used.

c. The color code was stenciled to the underside of the hood of each test vehicle to provide additional notification of the vehicles' test status.

Fleet Operation

On 25 August 1975, 97 commercial design vehicles began operating on an "extended-drain" oil evaluated program to determine the feasibility of extending the life of crankcase lubricants. Also, the program was designed to provide a quantitative comparison of performance, cost and environmental factors on synthetic versus mineral-base oils under normal military operating conditions for a two-year period. The vehicles continued normal routine service, that is, day-to-day operating activities, parking overnight exposed to the elements, etc. The only exceptions to the "business as usual" basis was:

TABLE 3. VEHICLES ASSIGNED TO BLUE FLEET
(AL-5009-L)

Vehicle Type	LEAD Bumper No.	Manufacturer	Year	Starting Mileage	Type Transmissions*
Sedan	A0005	Ford	1972	31,822	A
Station Wagon	A0291	Chev	1973	37,603	A
Bus (12 Pass.)	A0893	Checker	1969	**	M
Bus (25 Pass.)	A0900	IHC	1972	20,815	A
Truck Panel	A0102	Dodge	1972	15,345	A
Truck Carryall	A1013	Dodge	1974	25,786	A
Truck Pickup	A0155	Chev	1974	11,714	A
Truck Pickup	A0217	Chev	1974	20,804	A
Truck Pickup	A0200	Chev	1974	26,650	A
Truck Pickup	A0216	Chev	1974	22,466	A
Truck Pickup	A0214	Chev	1974	35,061	A
Truck Pickup	A0215	Chev	1974	37,173	A
Truck Van 21 MGVW	A0462	Dodge	1970	19,297	M
Truck Van 16-19 MGVW	A0482	IHC	1972	16,568	M
Truck Van 16-19 MGVW	A0475	IHC	1972	31,525	M
Truck Van 16-19 MGVW	A0469	Dodge	1971	16,330	M
Truck Van 16-19 MGVW	A0467	Dodge	1971	8,692	M
Truck S/P	A0561	IHC	1972	15,467	M
Truck S/P	A0549	Ford	1968	44,116	M
Truck S/P	A0533	Ford	1968	69,320	M
Truck S/P	A0558	IHC	1972	27,535	M
Truck Tractor 5-Ton	A0759	Ford	1967	65,417	M
Truck Tractor 5-Ton	A0765	Ford	1967	40,583	M
Truck Tractor 5-Ton	A0756	Ford	1967	49,290	M
Truck Dump 5-Ton	A0881	IHC	1971	34,416	M

* A = Automatic
M = Manual

** A0893 was dropped from vehicle inventory prior to program initiation--mileage was never recorded.

TABLE 4. VEHICLES ASSIGNED TO RED FLEET
(AL-5889-L)

Vehicle Type	LEAD Bumper No.	Manufacturer	Year	Starting Mileage	Type Transmission*
Sedan	A0004	Chev	1973	40,494	A
Sedan	A0041	AMC	1972	45,093	A
Bus (12 Pass.)	A0890	Checker	1969	57,696	M
Bus (25 Pass.)	A0898**	IHC	1972	19,263	A
Truck Panel	A0106	Chev	1971	43,410	A
Truck Carryall	A1010	Dodge	1974	8,638	A
Truck Pickup	A0148	Chev	1974	12,661	A
Truck Pickup	A0158	Chev	1974	21,480	A
Truck Pickup	A0159	Chev	1972	32,617	A
Truck Pickup	A0192	Chev	1972	25,754	A
Truck Pickup	A0154	Chev	1972	42,623	A
Truck Pickup	A0157	Chev	1972	37,836	A
Truck Van 21 MGVW	A0458	Dodge	1970	24,530	M
Truck Van 16-19 MGVW	A0471	IHC	1972	19,839	M
Truck Van 16-19 MGVW	A0477	IHC	1972	25,321	M
Truck Van 16-19 MGVW	A0464	Dodge	1971	37,245	M
Truck Van 16-19 MGVW	A0480	Chev	1972	27,495	M
Truck S/P	A0559	IHC	1972	17,254	M
Truck S/P	A0523	Ford	1968	72,842	M
Truck S/P	A0528**	Chev	1967	--	M
Truck Tractor 5-Ton	A0717	IHC	1970	30,103	M
Truck Tractor 5-Ton	A0718	Ford	1967	41,862	M
Truck Tractor 5-Ton	A0735	Ford	1968	55,907	M
Truck Dump 5-Ton	A0878	IHC	1971	36,621	M
Truck Dump 5-Ton	A0856	IHC	1969	51,166	M

* A = Automatic
M = Manual

** Prior to program initiation, this vehicle was moved to Yellow Fleet.

*** Prior to program initiation, this vehicle was eliminated--starting mileage was never recorded.

TABLE 5. VEHICLES ASSIGNED TO GREEN FLEET
(AL-5680-L)

Vehicle Type	LEAD Bumper No.	Manufacturer	Year	Starting Mileage	Type Transmission*
Sedan	A0006	Chev	1973	36,335	A
Sedan	A0043	AMC	1972	43,944	A
Station Wagon	A0289	Chev	1973	38,860	A
Bus (12 Pass.)	A0892	Checker	1973	26,527	A
Truck Panel	A0101	Chev	1971	30,327	M
Truck Carryall	A1012	Chev	1974	17,582	A
Truck Pickup	A0206	Chev	1974	17,388	A
Truck Pickup	A0156	Chev	1974	22,863	A
Truck Pickup	A0196	Chev	1974	27,528	A
Truck Pickup	A0213	Chev	1974	25,892	A
Truck Pickup	A0169	Chev	1974	42,038	A
Truck Pickup	A0171	Chev	1972	36,003	A
Truck Van 21 MGVW	A0461	Dodge	1970	23,389	M
Truck Van 16-19 MGVW	A0481	IHC	1972	16,497	M
Truck Van 16-19 MGVW	A0473	IHC	1972	36,364	M
Truck Van 16-19 MGVW	A0466	Dodge	1971	29,832	M
Truck Van 16-19 MGVW	A0478	IHC	1972	36,959	M
Truck S/P	A0557	IHC	1972	17,578	M
Truck S/P	A0535	Chev	1967	47,728	M
Truck S/P	A0589	Ford	1968	77,152	M
Truck Tractor 5-Ton	A0716	IHC	1970	36,249	M
Truck Tractor 5-Ton	A0728	Ford	1967	40,105	M
Truck Tractor 5-Ton	A0721	Ford	1967	48,666	M
Truck Dump 5-Ton	A0880	IHC	1971	32,088	M
Truck Dump 5-Ton	A0857	IHC	1969	40,178	M

* A = Automatic
M = Manual

TABLE 6. VEHICLES ASSIGNED TO YELLOW FLEET
(AL-6095-L)

Vehicle Type	LEAD Bumper No.	Manufacturer	Year	Starting Mileage	Type Transmission*
Sedan	A0042	AMC	1972	49,074	A
Station Wagon	A0281	Chev	1973	37,276	A
Bus (12 Pass.)	A0891	Checker	1973	29,865	A
Bus (25 Pass.)	A0898	IHC	1972	19,263	A
Truck Panel	A0104	Chev	1971	20,197	A
Truck Carryall	A1011	Dodge	1974	18,232	A
Truck Pickup	A0152	Chev	1974	13,952	A
Truck Pickup	A0199	Chev	1974	21,568	A
Truck Pickup	A0165	Chev	1972	29,434	A
Truck Pickup	A0197	Chev	1972	22,727	A
Truck Pickup	A0191	Chev	1972	41,095	A
Truck Pickup	A0194	Chev	1972	25,051	A
Truck Van 21 MGVW	A0459	Dodge	1970	15,916	M
Truck Van 16-19 MGVW	A0472	IHC	1972	21,721	M
Truck Van 16-19 MGVW	A0483	IHC	1972	23,190	M
Truck Van 16-19 MGVW	A0465	Dodge	1971	34,710	M
Truck Van 16-19 MGVW	A0470	IHC	1972	35,295	M
Truck S/P	A0560	IHC	1972	14,526	M
Truck S/P	A0541	Ford	1968	34,040	M
Truck S/P	A0526	Ford	1968	83,566	M
Truck S/P	A0534	Ford	1968	68,251	M
Truck Tractor 5-Ton	A0769	Ford	1967	65,867	M
Truck Tractor 5-Ton	A0722	Ford	1967	48,120	M
Truck Tractor 5-Ton	A0758	Ford	1967	61,766	M
Truck Dump 5-Ton	A0879	IHC	1971	35,217	M

* A = Automatic
M = Manual

a. Letterkenny Army Depot designated appropriate administrative and operational personnel who had responsibility for program execution.

b. Quantities of oil remaining in each drum, can, or other container were periodically measured to provide a cross-check against oil consumption calculations.

c. 50-ml samples of used oil were taken monthly from the oil dipstick hole of each vehicle on the program while the engine was at normal operating temperature. These samples were then immediately shipped to AFLRL for analysis. No make-up oil was added unless (through normal operation and/or sampling) the sump levels were reduced below the minimum allowable level.

d. Routine procedures were followed for needed oil additions. Quantities added and mileages were appropriately recorded and reported monthly to AFLRL so that consumption rates for each vehicle could be calculated. In addition, these reports included individual vehicle status, and any special comments on operation within the four fleets.

e. All oil filters were changed at the end of the first year's operation. Oil trapped in the filter housings was returned to the crankcase to eliminate excessive amounts of make-up oil.

Some vehicles were either deleted from the program or experienced engine changes due to high oil consumption and/or excessive camshaft lobe wear, or were subjected to oil changes at the request of AFLRL due to changes in viscosity, etc., that exceeded predetermined limits established for each of the four lubricating oils. The guidelines established for oil change criteria on viscosity and/or acid number are shown in Table 7.

TABLE 7. ESTIMATED GUIDELINES FOR OIL CHANGE CRITERIA

Estimated Guidelines	Fleets							
	Blue		Red		Green		Yellow	
	Min	Max	Min	Max	Min	Max	Min	Max
Viscosity at 100°F, cSt	40	110	45	110	60	130	50	120
TAN	--	7.0	--	7.0	--	7.0	--	7.0

Although these were only estimated guidelines, precautionary oil changes were made in a number of vehicles whenever the viscosity or acid number exceeded either the minimum or maximum established values, see Table 8 below:

TABLE 8. VEHICLES AFFECTED DURING "EXTENDED-DRAIN" EVALUATION

Fleet	Bumper No.	Item/Date Affected	Reason
Red	A0004	Oil change, 8-76	Wrong oil installed
Red	A0041	Dropped from inventory, 9-76	Accident
Red	A0464	Engine change, 12-76	Connecting rod failures
Red	A0718	Deleted from program, 5-76	High oil consumption
Red	A0735	Deleted from program, 5-76	High oil consumption
Blue	A0291	Oil change, 3-77	High viscosity and acid number
Blue	A0102	Oil change, 3-77	Acid number low
Blue	A0482	Dropped from inventory, 7-76	Accident
Blue	A0756	Deleted from program, 5-76	High oil consumption
Green	A0006	Oil change, 12-76	High viscosity and acid number
Green	A0289	Oil change, 12-76	High viscosity and acid number
Green	A0101	Engine replaced, 12-76	Cracked block
Green	A0206	Engine repairs, 9-76	Worn camshaft
Green	A0169	Oil change, 12-76	High viscosity
Green	A0171	Engine repairs, 12-76; oil change, 3-77	Worn camshaft; high viscosity
Green	A0535	Dropped from inventory, 2-76	Vehicle replacement plan
Green	A0716	Engine repairs	Engine overheated–both heads replaced
Green	A0721	Deleted from program, 5-76	High oil consumption
Yellow	A0281	Oil changes, 6-76 and 3-77	High viscosity
Yellow	A0891	Oil changes, 12-75 and 12-76	High viscosity
Yellow	A0152	Oil change, 7-76	High viscosity
Yellow	A0199	Oil changes, 6-76 and 3-77	High viscosity
Yellow	A0197	Engine repairs, oil change, 9-76	Worn camshaft
Yellow	A0541	Oil change, 3-77	Low viscosity
Yellow	A0534	Deleted from program, 5-76	Vehicle replacement plan
Yellow	A0769	Deleted from program, 6-76	Vehicle replacement plan
Yellow	A0722	Deleted from program, 5-76	High oil consumption
Yellow	A0758	Engine repairs, oil change, 2-76	Blown intake manifold gasket

RESULTS OF TEST

Used Oil Analysis

When the used oil samples were received at AFLRL, they were analyzed by the following procedures:

- All samples were subjected to a blotter test. The main purpose of which was to monitor additive depletion. The final size of the oil ring(s) formed by the oil sample on the blotter gives an indication how effective the additive is.
- On an alternating basis, approximately 1/2 of the used oil samples were checked for viscosity changes by the ASTM Method D-445.
- Acidity (TAN) tests were conducted in accordance with ASTM Method D-664 when either the blotter test and/or change in viscosity appeared abnormal.

As a result of the used oil analysis, and on the basis of viscosity and/or acid number increase/decrease, AFLRL recommended oil changes in 11 vehicles throughout this program. These vehicles are also shown in Table 8 and included the following:

Fleet	No. of Vehicles Requiring One Oil Change	No. of Vehicles Requiring Two Oil Changes
Blue	2	0
Red	0	0
Green	4	0
Yellow	2	3

Although only the above changes were recommended by AFLRL, the trend in viscosity increase for a significant number of vehicles indicated eventual lubricant change would be required.

Vehicle Maintenance

In addition to the lubricant changes indicated above, changes were required in seven vehicles because of engine repairs. Based on prior maintenance history developed during the three-year unleaded gasoline program conducted at Letterkenny, those repairs were not considered abnormal or associated with the current extended-drain program.

Used Oil Filter Inspection

Used oil filters were removed from sixteen (16) vehicles (8 on synthetic oils and 8 on mineral oils) at the end of the first year's operation and from the same vehicles again at the completion of the program. The filters were cut open, the filter paper removed and inspected for deposition and deterioration.

During the filter evaluation at the end of the first year, it was noted that all eight filters from the synthetic lubricants had brittle filter paper, whereas all eight filters using mineral oil had a pliable filter paper. No trend in deposition was observed between those filters using synthetic or mineral lubricants during the first year.

During inspection of the filters at the completion of the program (second year), it was noted that six (6) filters using the synthetic oils were brittle and two (2) were pliable, whereas four (4) filters using mineral oils were brittle and four (4) were pliable.

It appears from the above statements and Table 9 that filters used with synthetic lubricants have more of a tendency to become brittle than those used with mineral-base lubricants.

TABLE 9. USED-OIL FILTER INSPECTION DATA

Vehicle No.	Fleet	Type	Vehicle Make	Model	Test Miles Driven		Filter Manufacturer	Filter Condition[a]	
					1st Year	2nd Year		1st Year	2nd Year
A0291	Blue	Sta. Wagon	Chev	1973	16693	15699	Purolator	B	B
A0467	Blue	Trk, Van	Dodge	1971	9664	4853	Fram	B	P
A0533	Blue	Trk, S/P	Ford	1968	9107	5657	Fram	B	B
A0549	Blue	Trk, S/P	Ford	1968	6552	6519	Fram	B	B
A0006	Green	Sedan	Chev	1973	15653	17017	Purolator	B	B
A0169	Green	Trk, P/U	Chev	1974	15043	11873	Purolator	B	B
A0589	Green	Trk, S/P	Ford	1968	7846	5869	Fram	B	B
A0716	Green	Trk, 5-Ton	IHC	1970	3643	2165	IHC	B	P
A0199	Yellow	Trk, P/U	Chev	1974	14857	11440	Purolator	P	B
A0281	Yellow	Sta. Wagon	Chev	1973	15653	17100	Fram	P	P
A0758	Yellow	Trk, 5-Ton	Ford	1967	3407	3753	Fram	P	B
A0891	Yellow	Bus, 12-Pass	Checker	1973	12458	14402	Purolator	P	B
A0004	Red	Sedan	Chev	1973	16570	14213	Purolator	P	P
A0523	Red	Trk, S/P	Ford	1968	11662	8206	Fram	P	B
A0559	Red	Trk, S/P	IHC	1972	4973	4983	IHC	P	P
A0717	Red	Trk, 5-Ton	IHC	1970	3679	3208	IHC	P	P

[a]B – Brittle
P – Pliable

Deposition did not appear to be a factor in the extended use of the filters on either type lubricant. However, one filter used with mineral oil did show a visual increase in deposit during the second year's inspection.

Fuel Economy

Table 10 presents fuel economy data for all four fleets. Figure 1 depicts the same data in bar chart form with vehicles grouped according to type. Although there were differences in fuel economy between the four fleets, it is considered that these differences are most likely attributable to individual driver technique and/or specific vehicle mission requirement. A convenient overall comparison of fuel economy by fleets is shown below:

Fleet	Blue	Green	Red	Yellow	Avg. For All Vehicles
MPG	9.4	8.9	8.5	8.7	8.9
(KPL)	(4.0)	(3.8)	(3.6)	(3.7)	(3.8)

Oil Consumption

Oil consumption data for all four fleets is shown in Table 10, and again depicted in bar chart form in Figure 2. The oil consumption (MPQ) varied significantly between fleets with one synthetic and one mineral lubricant being better than the other synthetic and mineral oil. However, engine tolerances, operator interpretation of oil addition requirements, etc., probably influenced these consumption rates more so than the type of lubricant used. For convenient comparison, oil consumption (MPQ) is shown below for all four fleets plus the average for all vehicles completing the program:

Fleet	Blue	Green	Red	Yellow	Avg. for All Vehicles
MPQ	711	1082	729	933	851
(KPL)	(1209)	(1840)	(1240)	(1587)	(1477)

Ecological and Economic Comparisons

This program only addressed the environmental impact of waste oil disposal and did not investigate the possible changes in exhaust emissions caused by extended oil-drain intervals.

The environmental impact of waste crankcase oil disposal has been greatly reduced because of well-defined Army conservation policies which have emerged due to the increasing value of

TABLE 10. AVERAGE FUEL AND OIL CONSUMPTIONS

Vehicle No.	Fleet	Make	Year Model	Mileage		Average Consumptions			
				Starting	Net	Fuel		Oil	
						MPG	KPL	MPQ	KPL
Sedans(S)/Station Wagons(SW)									
A0005 (S)	Blue	Ford	1972	31822	19520	14.8	6.3	4880	8299
A0004 (S)	Red	Chev	1973	40494	29767	13.9	5.9	2290	3894
A0006 (S)	Green	Chev	1973	36335	31448	15.4	6.5	2246	3820
A0043 (S)	Green	AMC	1972	43944	38377	9.1	3.9	752	1279
A0042 (S)	Yellow	AMC	1972	49074	42254	8.9	3.8	587	998
A0291 (SW)	Blue	Chev	1973	37603	30407	11.5	4.9	2765	4702
A0289 (SW)	Green	Chev	1973	38860	25049	11.4	4.8	2783	4733
A0281 (SW)	Yellow	Chev	1973	37276	30306	13.2	5.6	3788	6442
12-Passenger Bus									
A0890	Red	Checker	1969	57696	13883	7.5	3.2	771	1311
A0891	Yellow	Checker	1973	29865	25529	8.6	3.7	1596	2714
A0892	Green	Checker	1973	26527	20256	11.0	4.7	2532	4306
25-Passenger Bus									
A0900	Blue	IHC	1972	20815	15169	6.7	2.8	506	861
A0898	Yellow	IHC	1972	19263	16040	6.0	2.6	844	1435
Truck, Panel									
A0102	Blue	Dodge	1972	15345	8837	10.8	4.6	589	1002
A0106	Red	Chev	1971	43410	17644	11.4	4.8	980	1667
A0101	Green	Chev	1971	30327	7191	8.4	3.6	1798	3058
A0104	Yellow	Chev	1971	20197	8063	8.9	3.8	1344	2286
Truck, Carryall									
A1013	Blue	Dodge	1974	25786	45545	12.3	5.2	911	1549
A1010	Red	Dodge	1974	8638	10360	8.5	3.6	471	801
A1012	Green	Chev	1974	17582	20146	14.6	6.2	593	1008
A1011	Yellow	Dodge	1974	18232	19278	8.3	3.5	419	713
Truck, Pickup									
A0155	Blue	Chev	1974	11714	13155	12.8	5.4	940	1599
A0217	Blue	Chev	1974	20804	11863	10.6	4.5	659	1121
A0200	Blue	Chev	1974	26650	14563	14.7	6.2	1214	2065
A0216	Blue	Chev	1974	22466	21664	8.8	3.7	656	1116
A0214	Blue	Chev	1974	35061	7890	8.9	3.8	1315	2236
A0215	Blue	Chev	1974	37173	10810	10.8	4.6	1081	1838
A0148	Red	Chev	1974	12661	11061	9.4	4.0	1383	2352
A0158	Red	Chev	1974	21480	14856	8.6	3.7	874	1486
A0159	Red	Chev	1972	32617	13239	6.9	2.9	2207	3753
A0192	Red	Chev	1972	25754	7608	7.4	3.1	692	1177
A0154	Red	Chev	1972	42623	14738	12.3	5.2	1228	2088
A0157	Red	Chev	1972	37836	14132	9.2	3.9	942	1602
A0206	Green	Chev	1974	17388	17706	10.5	4.5	2213	3763
A0156	Green	Chev	1974	22863	20696	9.2	3.9	862	1466
A0196	Green	Chev	1974	27528	30468	8.7	3.7	1904	3238
A0213	Green	Chev	1974	25892	9863	7.8	3.3	1973	3355
A0169	Green	Chev	1974	42038	26252	9.0	3.8	4375	7440
A0171	Green	Chev	1972	36003	10987	12.9	5.5	2197	3736
A0152	Yellow	Chev	1974	13952	20667	12.6	5.4	1879	3195
A0199	Yellow	Chev	1974	21568	30784	9.3	4.0	2052	3490
A0165	Yellow	Chev	1972	29434	17369	7.6	3.2	1737	2954

TABLE 10. AVERAGE FUEL AND OIL CONSUMPTIONS

Vehicle No.	Fleet	Make	Year Model	Mileage		Average Consumptions			
						Fuel		Oil	
				Starting	Net	MPG	KPL	MPQ	KPL
Truck, Pickup (Cont'd)									
A0197	Yellow	Chev	1972	22727	10047	8.4	3.6	1256	2136
A0191	Yellow	Chev	1972	41095	19150	9.5	4.0	2128	3619
A0194	Yellow	Chev	1972	25051	15429	9.5	4.0	1403	2386
Truck, Van, 21-MGVW									
A0462	Blue	Dodge	1970	19297	10434	11.0	4.7	652	1109
A0458	Red	Dodge	1970	24530	9930	5.9	2.5	709	1206
A0461	Green	Dodge	1970	23389	10146	6.8	2.9	780	1326
A0459	Yellow	Dodge	1970	15916	8650	7.5	3.2	481	818
Truck, Van, 16- to 19-MGVW									
A0475	Blue	IHC	1972	31525	19558	7.6	3.2	515	876
A0469	Blue	Dodge	1971	16330	7793	10.6	4.5	520	884
A0467	Blue	Dodge	1971	8692	14517	10.2	4.3	403	685
A0471	Red	IHC	1972	19839	11059	8.4	3.6	851	1447
A0477	Red	IHC	1972	25321	15116	8.2	3.5	521	886
A0464	Red	Dodge	1971	37245	22304	8.6	3.7	286	486
A0480	Red	Chev	1972	27495	13037	8.6	3.7	686	1167
A0481	Green	IHC	1972	16497	10045	7.2	3.1	1005	1709
A0473	Green	IHC	1972	36364	16631	8.1	3.4	1188	2020
A0466	Green	Dodge	1971	29832	12606	12.3	5.2	573	974
A0478	Green	IHC	1972	36959	24218	7.8	3.3	1345	2287
A0472	Yellow	IHC	1972	21721	13582	8.2	3.5	849	1444
A0483	Yellow	IHC	1972	23190	21515	12.4	5.3	935	1590
A0465	Yellow	Dodge	1971	34710	13419	9.2	3.9	671	1141
A0470	Yellow	IHC	1972	35295	16087	9.3	4.0	766	1303
Truck, S/P									
A0561	Blue	IHC	1972	15467	11614	8.3	3.5	581	988
A0549	Blue	Ford	1968	44116	12296	8.0	3.4	1537	2614
A0533	Blue	Ford	1968	69320	14426	8.5	3.6	1202	2044
A0558	Blue	IHC	1972	27535	21348	8.2	3.5	667	1134
A0559	Red	IHC	1972	17254	9364	8.3	3.5	669	1137
A0523	Red	Ford	1968	72842	19512	8.4	3.6	1394	2371
A0557	Green	IHC	1972	17578	10462	7.1	3.0	615	1046
A0589	Green	Ford	1967	77152	13225	6.1	2.6	1102	1874
A0560	Yellow	IHC	1972	14526	10692	7.7	3.3	668	1136
A0541	Yellow	Ford	1968	34040	6245	7.3	3.1	2082	3541
A0526	Yellow	Ford	1968	38566	17870	7.7	3.3	3574	6078
Truck, Tractor, 5-Ton									
A0759	Blue	Ford	1967	65417	17396	4.0	1.7	414	704
A0765	Blue	Ford	1967	40583	8210	4.1	1.7	200	340
A0717	Red	IHC	1970	30103	6444	4.3	1.8	322	548
A0716	Green	IHC	1970	36249	5450	4.6	2.0	248	422
A0728	Green	Ford	1967	40105	15689	4.1	1.7	872	1483
A0758	Yellow	Ford	1967	61766	6597	3.6	1.5	178	303
Truck, Dump, 5-Ton									
A0881	Blue	IHC	1971	34416	6453	4.1	1.7	323	549
A0878	Red	IHC	1971	36621	9578	6.8	2.9	368	626
A0856	Red	IHC	1969	51166	21368	8.2	3.5	890	1514
A0880	Green	IHC	1971	32088	5634	7.2	3.1	626	1065
A0857	Green	IHC	1969	40179	3718	5.7	2.4	207	352
A0879	Yellow	IHC	1971	35217	11016	8.2	3.5	612	1041

FIGURE 1. FUEL CONSUMPTION

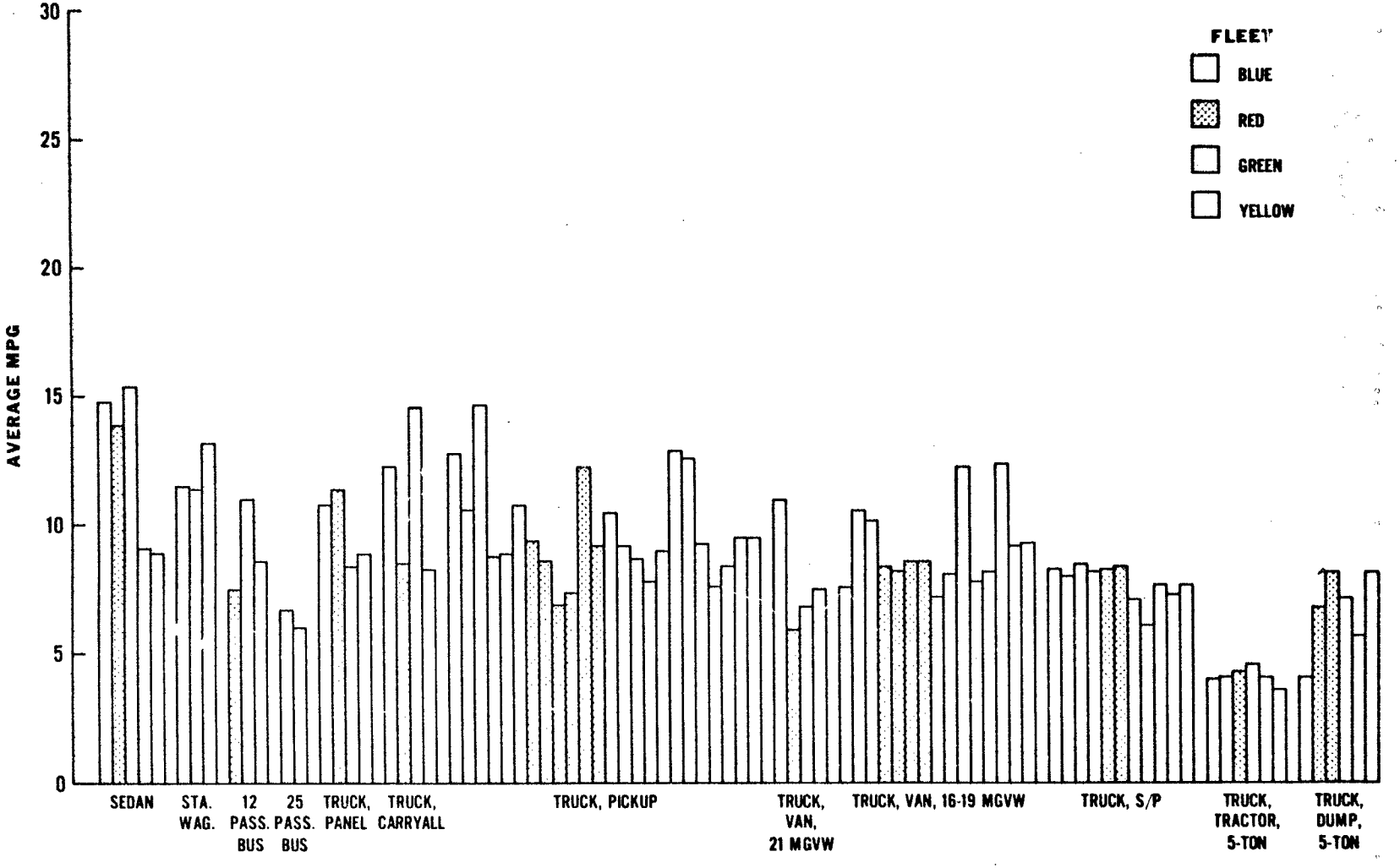
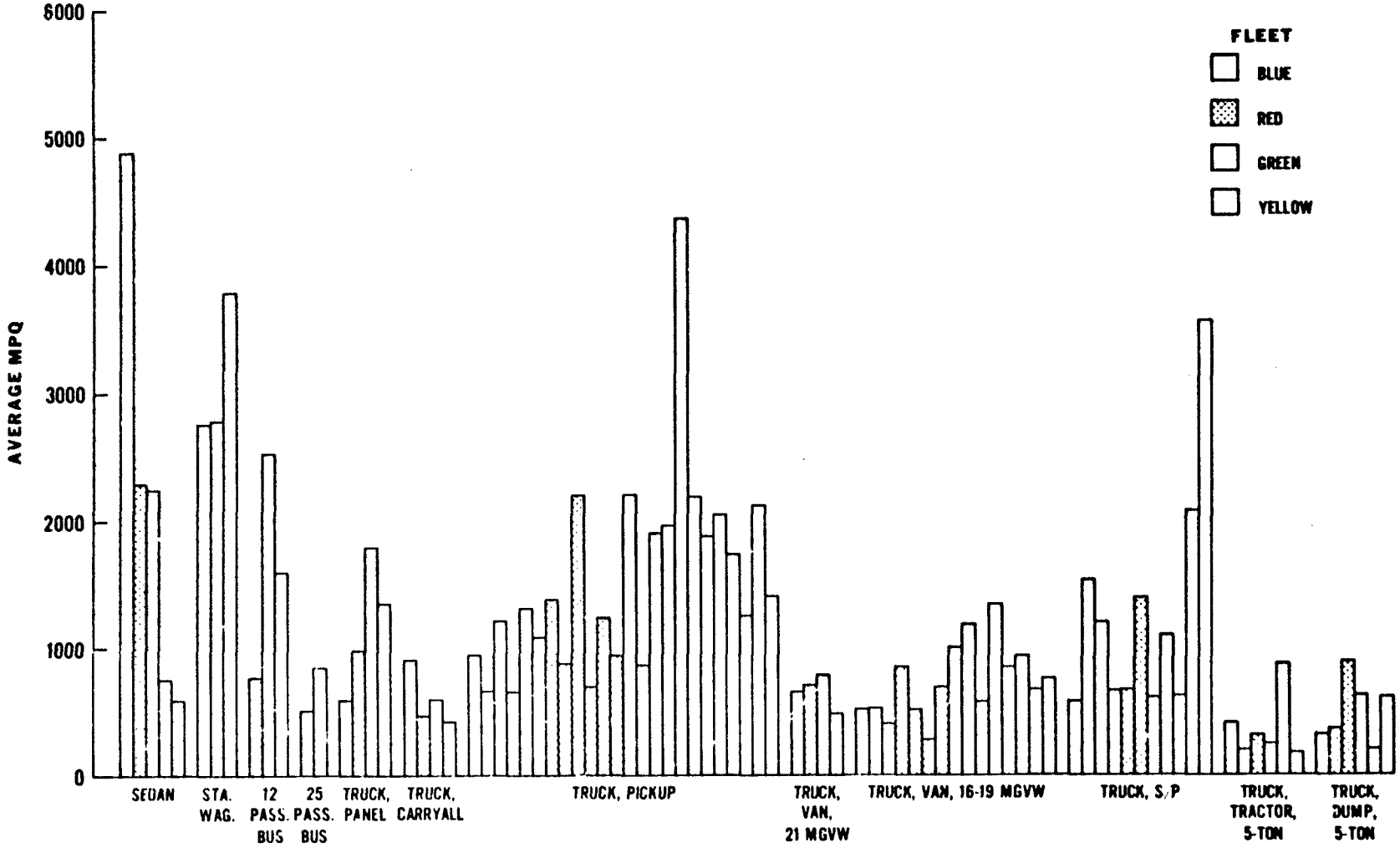


FIGURE 2. OIL CONSUMPTION



petroleum in recent years. It is, however, easily possible to make comparisons between the amounts of oil which theoretically would have had to be disposed of on a regular drain interval basis as compared to the actual amounts of drain oil which required storage or disposal as a direct result of several vehicles' drain oil samples exceeding the above-discussed oil change criteria. LEAD's practice for commercial vehicle crankcase lubricant drain and change had been (and presently continues to be) 3,000 miles or 90 days for those vehicles not participating in the extended-drain program. These criteria were used to calculate the waste oil which would have required disposal for each of the four fleets had they continued on a regular basis with utilization (mileage) as experienced in this program. For Yellow fleet (mineral-base oil) makeup and oil drains required 124 gallons of replacement oil (see Table 11). On a regular drain basis during this same time, 271 gallons of oil would have been required. There is thus an approximate 2:1 oil savings ratio for this fleet. Comparably, Red fleet required 106 gallons, while on a regular drain basis the fleet would have required 229 gallons of oil. This gives a 2:1 oil savings ratio. Green fleet used 98 gallons of makeup and drain oil. On a regular drain basis, 273 gallons would have been required with a resulting 3:1 oil savings ratio. Finally, Blue fleet required a total of 125 gallons, whereas on a regular drain basis the fleet would have required 262 gallons for a 2:1 oil savings ratio. Pooling all these statistics, 453 gallons of makeup and drain refill lubricant were required for the program. Had the four test fleets been operated on a regular drain basis, 1,035 gallons would have required disposal. This results in an overall savings ratio of 2:1.

Total cost of oil and filters for Yellow fleet during this two-year period was $239.14 (see Table 12). Yellow fleet's utilization was 380,589 miles, resulting in a unit lubricant cost of 0.063 cents per mile. Red fleet oil and filter costs were $179.55 with 285,000 miles utilization, resulting in exactly the same figure of 0.063 cents per mile. This duplication of statistics is purely accidental and can be accounted for by the fact that Yellow fleet lubricant cost $1.59 per gallon, whereas Red fleet lubricant cost only $1.38 per gallon. Blue fleet lubricant (synthetic) cost $4.81 per gallon and total oil and filter costs were $641.98. Blue fleet utilization was 343,468 miles resulting in a unit cost of 0.187 cents per mile. Green fleet lubricant (also synthetic) cost was $4.50 per gallon. Total oil and filter cost for Green fleet was $477.58 with a utilization of 386,263 miles resulting in a unit cost of 0.124 cents per mile. Obviously, the two mineral oils provide a significant unit cost advantage over the synthetic lubricants employed. In addition, Table 12 shows unit costs for assumed regular-drain operation for each fleet's total mileage. The unit costs shown in this table include oil and filter cost only, labor charges were not considered

TABLE 11. COMPARISON OF OIL CONSUMPTION FOR EXTENDED AND REGULAR DRAINS

Fleet	Total Oil Required, gal. Extended Drain*	Regular Drain**	Oil Savings Ratio
Yellow	124	271	2.19
Red	106	229	2.16
Green	98	273	2.79
Blue	125	262	2.10
	453	1035	

* Makeup and drain oil.

** 3000 miles or 90 days.

TABLE 12. OIL AND FILTER COSTS FOR EXTENDED-DRAIN OPERATION COMPARISON

Fleet	Total Mileage	Extended Drain Oil + Filter Cost	Regular Drain Oil + Filter Cost	Unit Cost, ¢/mi Extended Drain	Unit Cost, ¢/mi Regular Drain
Yellow	380,589	$239.14	$1352.64	0.063	0.355
Red	280,000	179.55	1079.48	0.063	0.379
Blue	343,468	641.98	2176.75	0.187	0.634
Green	386,263	477.58	2208.99	0.124	0.572

in arriving at these estimated costs. As can be seen by the unit cost per mile in Table 12, the mineral oils provide roughly a 6:1 savings and the synthetics roughly a 3:1 savings primarily due to the higher cost of the synthetics.

Operational Evaluation

Utilizing 87 commercial design Army vehicles (administrative-type) in a two-year extended-drain oil evaluation program, approximately 1.4 million vehicle miles were accumulated. Eleven vehicles had precautionary oil changes due to viscosity and/or acid number changes. Also, 7 other vehicles had oil changes due to other factors (see Table 7). Sixty-nine (69) of the 87 vehicles continued through the program without oil drains with an average mileage of 15,010 miles. The range of mileage accumulated on these vehicles varied between 3,718 and 45,545 miles.

CONCLUSIONS

Specific conclusions derived from this program were:

- Extended-drain operations appear feasible for administrative-type vehicles when oil properties are monitored. However, more data are required relative to determining engine degradation before such procedures can be adopted.
- There is definite evidence that both synthetic lubricants caused increased filter deterioration when used for extended oil drain periods during this program.
- Used oil storage and disposal problems are significantly reduced through extended-drain operation.
- Because of the lower mineral oil prices, the unit lubricant cost per mile was significantly less than the unit cost per mile for the two synthetics.

RECOMMENDATIONS

As a result of this program, the following recommendations are deemed appropriate:

- Conduct field test with administrative-type vehicles (both gasoline and diesel) to obtain data relevant to extended drain effects on engine deposition and to expand the oil analysis program.
- Develop extended-drain technology for combat/tactical vehicles.
- Develop a field test kit which will define simple analytical procedures for evaluating used oil condition with respect to oil change criteria.

BIBLIOGRAPHY

1. "Research Test of Lubricants, Engine Sub-Zero", Jon Dufenach and SP4 Charles Slavin, Final Letter Report, Scientific and Engineering, USAATC, APO Seattle 98733 (USATECOM Project No. 7-5-0053-04), May 1969.

2. "Development of Internal-Combustion Engine Lubricants for Sub-Zero Operation", T.C. Bowen, USARDC-CCL, Report No. 265, AD693866, September 1969.

3. Method 354, Federal Test Method Std. 791B, "Performance of Arctic Lubricating Oils in a Two-Cycle Diesel Engine Under Steady State Turbosupercharged Conditions", January 1973.

4. Lestz, S.J., "Development of a Diesel Engine Test Technique For Evaluating Arctic Engine Oils", Final Report AFLRL No. 24, September 1973, AD68901.

5. Status Report of AFLRL Position Paper on Single Lubricant/Never-Drain Engine Oil Concept, Letter (File: F7-3672 and G3-7372) AFLRL to USAMERDC, STSFB-GL, dated 13 August 1974.

6. AFLRL Position Paper, "Single Lubricant/Never-Drain Engine Oil Concept", Letter (File: F7-3672 and G3-7372) AFLRL to USAMERDC, STSFB-GL, 17 October 1974.

7. Lestz, S.J., Bowen, T.C., "Army Experience With Synthetic Engine Oils in Mixed Fleet Arctic Service", SAE Paper 750685 for presentation at National F&L Meeting, Houston, Texas, 2-5 June 1975.

8. Lestz, Sidney J. and Bowen, Thomas C., "Development of Army Synthetic Automotive Engine Oils for Arctic Service", AFLRL Interim Report No. 73, AD A019113, September 1975.

9. Owens, E.C., et al, "Never-Drain Engine Oil Technology", USAFLRL Interim Report No. 49, AD A012777, June 1975.

10. Owens, E.C., et al, "Never-Drain Engine Oil Technology, Phase II", USAFLRL Report No. 72, AD A023256, October 1975.

11. Lestz, S.J., Russell, J.A., Bowen, T.C., and LePera, M.E., "Evaluation of Synthetic Automotive Crankcase Lubricants for Military Application", AFLRL Interim Report No. 71, AD A023613, December 1975.

12. Tosh, J.D., "Performance of Army Engines With Unleaded Gasoline", AFLRL Report No. 82, AD A032075, October 1976.

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